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1 TITLE OF THE INVENTION

2 VEHICLE SURROUNDINGS MONITORING APPARATUS AND TRAVELING CONTROL

3 SYSTEM INCORPORATING THE APPARATUS

4

5 BACKGROUND OF THE INVENTION

6 1. Field of the invention

7 The present invention relates to a vehicle surroundings
8 monitoring apparatus for recognizing traveling circumstances
9 in front of an own vehicle by stereoscopic cameras, monocular
10 cameras, millimeter wave radars, and the like and for making an
11 accurate judgment of evacuation of a preceding vehicle from the
12 lane and, more particularly to a traveling control system
13 incorporating such a vehicle surroundings monitoring apparatus.

14 2. Discussion of related arts

15 In recent years, such a traveling control system as
16 detecting traveling circumstances in front of an own vehicle by
17 a camera and the like mounted on a vehicle, estimating traveling
18 paths of the own vehicle from the traveling circumstances data,
19 detecting a preceding vehicle traveling ahead of the own vehicle
20 and making a follow-up control of the preceding vehicle or an
21 intervehicle distance control between the own vehicle and the
22 preceding vehicle, has been put into practical use.

23 For example, Japanese Patent Application Laid-open No.
24 Toku-Kai-Hei 9-91598 discloses a traveling control system in which
25 a traveling path of an own vehicle is estimated from traveling

1 conditions such as yaw rate and other data and a nearest obstacle
2 on the traveling path is detected as a preceding vehicle to be
3 monitored. Further, in the traveling control system, when the
4 preceding vehicle goes out of the traveling path of the own vehicle,
5 the monitoring of the preceding vehicle is released.

6 In the traveling control system, the technology of
7 recognizing a preceding vehicle is very important. The preceding
8 vehicle sometimes travels in such a manner as trying to avoid
9 an obstacle, sometimes changes the lane, and sometimes goes out
10 of the lane and other vehicle enters the lane in place of the
11 preceding vehicle. If the traveling control system fails to
12 correctly catch the behavior of the preceding vehicle, the
13 traveling control becomes awkward and rather inconvenient for
14 a vehicle driver.

15

16 SUMMARY OF THE INVENTION

17 It is an object of the present invention to provide
18 a vehicle surroundings monitoring apparatus capable of accurately
19 continuing to monitor a preceding vehicle and catching behaviors
20 of the preceding vehicle such as evacuation of a preceding vehicle
21 from a traveling path of an own vehicle, intrusion of a different
22 vehicle in place of the preceding vehicle and the like with quick
23 response and to provide a traveling control system incorporating
24 such a vehicle surroundings monitoring apparatus.

25 In order to attain the object, a vehicle surroundings

1 monitoring apparatus, comprises frontal information detecting
2 means for detecting solid object information in front of an own
3 vehicle, preceding vehicle recognizing means for recognizing a
4 preceding vehicle based on the solid object information,
5 traveling path estimating means for estimating a traveling path
6 of the own vehicle, first evacuation possibility judging means
7 for judging a first possibility of relative evacuation between
8 the preceding vehicle and the own vehicle according to positions
9 of the preceding vehicle and the own vehicle, second evacuation
10 possibility judging means for judging a second possibility of
11 relative evacuation between the preceding vehicle and the own
12 vehicle according to information of solid objects other than the
13 preceding vehicle, and preceding vehicle evacuation possibility
14 judging means for judging a final possibility of relative
15 evacuation between the preceding vehicle and the own vehicle based
16 on the first possibility and the second possibility.

17

18 BRIEF DESCRIPTION OF THE DRAWINGS

19 Fig. 1 is a schematic diagram showing a traveling control
20 system incorporating a vehicle surroundings monitoring apparatus
21 according to the present invention;

22 Fig. 2 is a flowchart showing a routine for monitoring
23 surroundings of a vehicle;

24 Fig. 3 is a flowchart showing a routine for estimating
25 a traveling path of an own vehicle;

1 Fig. 4 is a flowchart showing a routine for judging
2 the possibility of evacuation of a preceding vehicle using a
3 traveling path C of an own vehicle;

4 Fig. 5a is an explanatory diagram showing a process
5 of producing a new traveling path C of an own vehicle from the
6 traveling path A and the traveling path B;

7 Fig. 5b is an explanatory diagram showing a process
8 of producing the new traveling path C when the traveling path
9 A is erroneously recognized;

10 Fig. 5c is an explanatory diagram showing a process
11 of calculating a new traveling path E from the traveling path
12 C and the traveling path D (traveling path of a preceding vehicle);
13 and

14 Fig. 6 is an explanatory diagram showing a process for
15 establishing a judging counter.

16

17

18 DESCRIPTION OF THE PREFERRED EMBODIMENT

19 Referring now to Fig. 1, reference numeral 1 denotes
20 a vehicle (own vehicle) on which an intervehicle distance
21 automatically adjusting system (Adaptive Cruise Control: ACC)
22 2 is mounted. The ACC system 2 is constituted by a traveling control
23 unit 3, a stereoscopic camera 4 and a vehicle surroundings
24 monitoring apparatus 5. When the ACC system is set to a constant
25 speed control mode, the vehicle travels at a speed established

1 by a vehicle driver and when the system is set to a follow-up
2 traveling control mode, the vehicle travels at a speed targeted
3 to the speed of a preceding vehicle with a constant intervehicle
4 distance to the preceding vehicle maintained.

5 The stereoscopic camera 4 constituting vehicle forward
6 information detecting means is composed of a pair (left and right)
7 of CCD cameras using a solid-state image component such as Charge
8 Coupled Device and the left and right cameras are transversely
9 mounted on a front ceiling of a passenger compartment at a specified
10 interval of distance, respectively. The respective cameras take
11 picture images of an outside object from different view points
12 and input the picture images to the vehicle surroundings monitoring
13 apparatus 5.

14 Further, the vehicle 1 has a vehicle speed sensor 6
15 for detecting a vehicle speed and the detected vehicle speed is
16 inputted to the traveling control unit 3 and the vehicle
17 surroundings monitoring apparatus 5, respectively. Further, the
18 vehicle 1 has a steering angle sensor 7 for detecting a steering
19 angle and a yaw rate sensor 8 for detecting a yaw rate and the
20 detected steering angle and yaw rate signals are inputted to the
21 vehicle surroundings monitoring apparatus 5. Further, a signal
22 from a turn signal switch 9 is inputted to the vehicle surroundings
23 monitoring apparatus 5. These sensors 6, 7, 8 and the switch 9
24 act as own vehicle traveling conditions detecting means.

25 The vehicle surroundings monitoring apparatus 5 inputs

1 respective signals indicative of picture images from the
2 stereoscopic camera 4, vehicle speeds, steering angle, yaw rate
3 and turn signal and detects frontal information about solid objects,
4 side walls and lane markers in front of the vehicle 1 based on
5 the picture images inputted from the stereoscopic camera 4. Then,
6 the apparatus estimates several traveling paths of the own vehicle
7 1 from the frontal information and traveling conditions of the
8 own vehicle 1 according to the flowchart which will be described
9 hereinafter and estimates a final traveling path of the own vehicle
10 1 from those traveling paths. Further, the apparatus establishes
11 a traveling region A corresponding to a detected solid object
12 based on the final traveling path. Further, the apparatus
13 establishes a traveling region B corresponding to the solid object
14 based on at least either of the traveling region A and the traveling
15 road information and judges whether the solid object is a preceding
16 vehicle, a tentative preceding vehicle or others according to
17 the state of existence of the solid object in the traveling regions
18 A and B. As a result of the judgment, a preceding vehicle in front
19 of the own vehicle 1 is extracted and the result is outputted
20 to the traveling control unit 3.

21 Describing the process of estimating the traveling path
22 of the own vehicle (hereinafter referred to as "own traveling
23 path") in brief, a new own traveling path C is calculated from
24 the own traveling path A (first own traveling path) obtained based
25 on lane markers and side walls and the own traveling path B (second

1 own traveling path) obtained based on yaw rates of the own vehicle.
2 Then, the possibility of evacuation of the preceding vehicle is
3 judged from the relationship between the own traveling path C,
4 the preceding vehicle and the solid object in the vicinity of
5 the preceding vehicle. In case where there is no possibility of
6 evacuation of the preceding vehicle, the turn signal switch is
7 turned off, and the absolute value of the steering wheel rotation
8 angle is smaller than a specified value, a new own traveling path
9 E is calculated from the own traveling path C and the locus of
10 the preceding vehicle and a present own traveling path is
11 calculated from the own traveling path E and the previous own
12 traveling path. On the other hand, in case where the conditions
13 described above are not satisfied, a present own traveling path
14 is calculated from the own traveling path C and the previous own
15 traveling path. The vehicle surroundings monitoring apparatus
16 5 comprises forward information detecting means, preceding vehicle
17 recognizing means, own traveling path estimating means, first
18 evacuation possibility judging means and second evacuation
19 possibility judging means.

20 Describing the processing of images from the
21 stereoscopic camera 4 in the vehicle surroundings monitoring
22 apparatus 5, with respect to a pair of stereoscopic images taken
23 by the stereoscopic CCD camera 4, distance information over the
24 entire image is obtained from the deviation amount between
25 corresponding positions according to the principle of

1 trianguration and a distance image representing
2 three-dimensional distance distribution is formed based on the
3 distance information. Then, lane marker data, side wall data such
4 as guardrails, curbs and side walls arranged along the road and
5 solid object data such as vehicles and the like, are extracted
6 by means of the known grouping process and the like by comparing
7 the distance image with the three-dimensional road profile data,
8 side wall data, solid object data and the like stored beforehand.
9 Thus extracted lane marker data, side wall data and solid object
10 data are denoted by different numbers respectively. Further, the
11 solid object data are classified into three kinds of objects,
12 a backward moving object moving toward the own vehicle 1, a still
13 object in standstill and a forward moving object moving in the
14 same direction as the own vehicle 1 based on the relationship
15 between the relative variation of the distance from the own vehicle
16 and the vehicle speed of the own vehicle 1 and the respective
17 solid object data are outputted.

18 The traveling control unit 3 is equipped with a function
19 of a constant speed traveling control for maintaining the vehicle
20 speed at a value inputted by the vehicle driver and a function
21 of a follow-up traveling control for following up the preceding
22 vehicle in a condition to keep the intervehicle distance between
23 the own vehicle 1 and the preceding vehicle constant. The traveling
24 control unit 3 is connected with a constant speed traveling switch
25 10 constituted by a plurality of switches operated by a constant

1 speed traveling selector lever provided on the side surface of
2 a steering column, the vehicle surroundings monitoring apparatus
3 5, the vehicle speed sensor 6 and the like.

4 The constant speed traveling switch 10 is constituted
5 by a speed setting switch for setting a target vehicle speed at
6 the constant speed traveling mode, a coast switch for changing
7 the target vehicle speed in a descending direction and a resume
8 switch for changing the target vehicle speed in an ascending
9 direction. Further, a main switch (not shown) for turning the
10 traveling control on or off is disposed in the vicinity of the
11 constant speed traveling selector lever.

12 When the driver turns a main switch (not shown) on and
13 sets a desired vehicle speed by operating the constant speed
14 traveling selector lever, a signal indicative of the desired
15 vehicle speed inputs from the constant speed traveling switch
16 10 to the traveling control unit 3 and a throttle valve 12 driven
17 by a throttle actuator 11 makes a feed-back control so as to converge
18 the vehicle speed detected by the vehicle speed sensor 6 to the
19 established vehicle speed. As a result, the own vehicle 1 can
20 travel at a constant speed automatically.

21 Further, when the traveling control unit 3 makes a
22 constant traveling control, supposing a case where the vehicle
23 surroundings monitoring apparatus 5 recognizes a preceding
24 vehicle, which is traveling at a lower speed than the established
25 vehicle speed, the traveling control unit 3 automatically changes

1 over to a follow-up traveling control mode in which the own vehicle
2 travels in a condition retaining at a constant intervehicle
3 distance.

4 When the constant speed traveling control mode is
5 transferred to the follow-up traveling control mode, a target
6 value of an appropriate intervehicle distance between the own
7 vehicle 1 and the preceding vehicle is established based on the
8 intervehicle distance obtained from the vehicle surroundings
9 monitoring apparatus 5, the vehicle speed of the own vehicle 1
10 detected by the vehicle speed sensor 6 and the vehicle speed of
11 the preceding vehicle obtained from the intervehicle distance
12 and the vehicle speed of the own vehicle 1. Further, the traveling
13 control unit 3 outputs a drive signal to the throttle actuator
14 11 and makes a feed-back control of the opening angle of the throttle
15 valve 12 so that the intervehicle distance agrees with the target
16 value and controls the own vehicle 1 in a condition following
17 up the preceding vehicle with the intervehicle distance retained.

18 Next, a vehicle surroundings monitoring program of the
19 vehicle surroundings monitoring apparatus 5 will be described
20 by referring to a flowchart shown in Fig. 2.

21 In this embodiment, the coordinate system of the
22 three-dimensional real space is transferred to a coordinate system
23 fixed to the own vehicle. That is, the coordinate system is composed
24 of X coordinate extending in a widthwise direction of the own
25 vehicle, Y coordinate extending in a vertical direction of the

1 own vehicle, Z coordinate extending in a lengthwise direction
2 of the own vehicle and an origin of the coordinate placed on the
3 road surface directly underneath the central point of two CCD
4 cameras. The positive sides of X, Y and Z coordinates are
5 established in a right direction, in an upward direction and in
6 a forward direction, respectively.

7 The routine shown in Fig. 2 is energized every 50
8 milliseconds. First at a step (hereinafter abbreviated as S) 101,
9 solid object data, side wall data including guardrails, curbs
10 provided along the road and lane marker data are recognized based
11 on images taken by the stereoscopic camera 4. Further, with respect
12 to the solid object data, they are classified into three kinds
13 of objects, backward moving objects, still objects and forward
14 moving objects as described above.

15 Next, the program goes to S102 where the traveling path
16 of the own vehicle is estimated according to a flowchart which
17 will be described hereinafter shown in Fig. 3. First, at S201,
18 the presently obtained own traveling path $Xpr(n)[i]$ is stored
19 as a previous own traveling path $Xpr(n-1)[i]$. [I] denotes node
20 numbers (segment numbers) attached to the own traveling path
21 extending forward from the own vehicle 1. In this embodiment,
22 the own traveling path has 24 segments in a forward direction
23 and is composed of a plurality of straight lines connected with
24 each other. Accordingly, Z coordinate at the segment i is
25 established as follows.

1 Z coordinate at segment $i = 10.24$ meters
2 $+ i \cdot 4.096$ meters ($I = 0$ to 23)

3 Then, the program goes to S202 where an own traveling
4 A ($Xpra[i]$, $i = 0$ to 23) is calculated according to the following
5 method A or B.

6 **Method A: Estimation of traveling path based on lane markers**

7 In case where both or either of left and right lane
8 markers data are obtained and the profile of the lane on which
9 the own vehicle 1 travels can be estimated from these lane markers
10 data, the traveling path of the own vehicle is formed in parallel
11 with the lane markers in consideration of the width of the own
12 vehicle 1 and the position of the own vehicle 1 in the present
13 lane.

14 **Method B: Estimation of traveling path based on side wall data**

15 In case where both or either of left and right side
16 walls data are obtained and the profile of the lane on which the
17 own vehicle 1 travels can be estimated from these side walls data,
18 the traveling path of the own vehicle is formed in parallel with
19 the side walls in consideration of the width of the own vehicle
20 1 and the position of the own vehicle 1 in the present lane.

21 In case where the own traveling path A can not be
22 established according to any of the methods A, B, it is calculated
23 according to the following methods C or D.

24 **Method C: Estimation of traveling path based on a trace of the**
25 **preceding vehicle**

1 The own traveling path is estimated based on the past
2 traveling trace extracted from the solid object data of the
3 preceding vehicle.

4 **Method D: Estimation of path based on trace of the own vehicle**

5 The own traveling path is estimated based on the
6 traveling conditions such as yaw rate γ , vehicle speed V and
7 steering wheel rotation angle θ_H of the own vehicle 1.

8 After that, the program goes to S203 in which an own
9 traveling path B ($X_{prb}[I]$, $I = 0$ to 23) is calculated based on
10 the yaw rate γ according to the following processes.

11
$$X_{prb}[i] = \gamma \cdot Z^2 + 10240 \text{ (millimeters)}$$

12
$$Z = 4096 \cdot i + 10240 \text{ (millimeters)}$$

13 Thus obtained own traveling path B ($X_{prb}[i]$) is
14 corrected as follows by the state of the steering wheel rotation
15 angle θ_H , that is, by respective states, during traveling
16 straightforwardly, during turning a curve and during returning
17 the steering wheel to straight.

18
$$X_{prb}[i] = X_{prb}[i] \cdot \alpha$$

19 where α is a correction coefficient.

20 The correction coefficient α is established to a value
21 ($\neq 0$) from 0 to 1.0. When the vehicle travels straight or when
22 the vehicle transfers from curve to straight, the correction
23 coefficient α is established to a small value so as to reduce
24 the curvature of the traveling path. When the vehicle turns a
25 curve, the correction coefficient α is established to 1.0 so as

1 to employ the curvature derived from the yaw rate γ as it is.

2 Then, the program goes to S204 where an own traveling
3 path C ($X_{prc}[i]$, $i = 0$ to 23) is calculated based on the own traveling
4 path A ($X_{pra}[i]$, $i = 0$ to 23) and the own traveling path B ($X_{prb}[i]$,
5 $i = 0$ to 23) as shown in Fig. 5a.

6
$$X_{prc}[i] = (X_{pra}[i] \cdot \lambda + X_{prb}[i] \cdot \mu) / (\lambda + \mu)$$

7 where λ and μ are values varying according to the result of
8 recognition of circumstances such as road widths.

9 Thus, in case where the accuracy of the own traveling
10 path A ($X_{pra}[i]$, $i = 0$ to 23) is exacerbated by erroneous recognition
11 of lane markers or side walls as shown in Fig. 5b, for example,
12 the recognition accuracy of the own traveling path can be prevented
13 from going down by primarily using the own traveling path B
14 ($X_{prb}[i]$, $i = 0$ to 23) by means of establishing μ to a larger
15 value than λ .

16 Then, the program goes to S205 in which it is judged
17 whether or not a preceding vehicle is detected and if detected,
18 the program goes to S206 where the segment kpo on Z coordinate
19 of the preceding vehicle is established as follows:

20
$$Kpo = (Z \text{ coordinate of preceding vehicle} - 10.24) / 4.096$$

21 Then, the program goes to S207 in which the possibility
22 of evacuation of the preceding vehicle is judged using the own
23 traveling path C ($X_{prc}[i]$, $i = 0$ to 23) calculated at S204,
24 according to a flowchart shown in Fig. 4.

25 In this routine, first, at S301, it is judged whether

1 or not a preceding vehicle exists. If there is no preceding, the
2 program goes to S302 wherein a judging counter TIME is cleared
3 (TIME = 0) and then goes to S303 wherein it is judged that there
4 is no preceding vehicle and such a signal is outputted, leaving
5 the routine. In this embodiment, the signal is the same as a signal
6 indicating that there is a possibility of evacuation of the
7 preceding vehicle. Further, the aforesaid judging counter TIME
8 is for expressing the possibility of evacuation of the preceding
9 vehicle numerically.

10 On the other hand, in case where it is judged at S301
11 that there is a preceding vehicle, the program goes to S304 where
12 the absolute value CAL of the difference between X coordinate
13 kpx of the preceding vehicle and X coordinate of the own traveling
14 path C (Xprc[i], i = 0 to 23) on Z coordinate of the preceding
15 vehicle, is calculated (CAL = |kpx - xpx|).

16 The processes from S305 to S311 will be described by
17 reference to Fig. 6.

18 First, at S305, it is judged whether or not the segment
19 kpo of Z coordinate of the preceding vehicle is larger than 17.
20 that is, the division is more than 80 meters ahead. If kpo is
21 larger than 17, the program goes to S306 in which the judging
22 counter TIME is cleared (TIME = 0) and then goes to S307 a signal
23 indicative of no possibility of evacuation of the preceding vehicle
24 is outputted, leaving the routine.

25 Further, in case where it is judged at S305 that the

1 segment kpo of Z coordinate of the preceding vehicle is smaller
2 than 80 meters, the program goes to S308 in which the judgment
3 counter TIME is initialized according to the position of the
4 preceding vehicle as follows (first evacuation possibility judging
5 means):

6 A. In case where CAL is smaller than 500 millimeters, that is,
7 the preceding vehicle is in the vicinity of the traveling path
8 of the own vehicle (region 1 of Fig. 6),

9 TIME = 0

10 B. In case where CAL is larger than 500 millimeters, that is,
11 the preceding vehicle is regarded as traveling apart from the
12 traveling path of the own vehicle

13 (1) In case where the segment kpo of Z coordinate of the
14 preceding vehicle is smaller than 80 meters and larger than 50
15 meters:

16 In case of $2000 \leq CAL \leq 3000$ millimeters (region II of
17 Fig, 6)

18 TIME = TIME + 5

19 In case of other than above (particularly, outside of
20 the region II, note that the preceding vehicle travels
21 around curves)

22 TIME = TIME - 5

23 (2) In case where the segment kpo of Z coordinate of the
24 preceding vehicle is smaller than 50 meters and larger than 30
25 meters:

1 In case of $1500 \leq \text{CAL} \leq 2500$ millimeters (region III of
2 Fig. 6)
3 $\text{TIME} = \text{TIME} + 10$
4 In case of other than above (particularly, outside of
5 the region III, note that the preceding vehicle travels
6 around curves)
7 $\text{TIME} = \text{TIME} - 10$
8 (3) In case where the segment of kpo of Z coordinate of
9 the preceding vehicle is smaller than 30 meters:
10 In case of $\text{CAL} \geq 1000$ millimeters (region IV of Fig. 6)
11 $\text{TIME} = \text{TIME} + 30$
12 In case other than above
13 $\text{TIME} = \text{TIME} - 10$
14 Then, the program goes to S309 wherein the judging
15 counter TIME is established by the solid object other than the
16 preceding vehicle (second evacuation possibility judging means).
17 For example, in case where a forward traveling solid object enters
18 a traveling region kpo ± 1 , the judging counter TIME initialized
19 by S308 is additionally initialized as follows:
20 $\text{TIME} = \text{TIME} + 10$
21 Then, the program goes to S310 in which it is judged
22 whether or not TIME is larger than a threshold value (for example
23 100). If TIME is smaller than 100, the program goes to S307 where
24 after a signal indicative of no possibility of evacuation of the
25 preceding vehicle is outputted, the program leaves the routine.

1 If TIME is larger than 100, the program goes to S311 where a signal
2 indicative of the possibility of evacuation of the preceding
3 vehicle is outputted and leaves the routine. Thus, since the
4 judgment of evacuation of the preceding vehicle is made by the
5 own traveling path C (Xprc[i], i = 0 to 23) and the position where
6 the preceding vehicle exists, even when no lane markers are seen,
7 an accurate judgment of evacuation of the preceding vehicle is
8 available. Further, the accurate judgment of evacuation of the
9 preceding vehicle can prevent the ACC system from following up
10 the preceding vehicle hazardously.

11 Since the introduction of this evacuation judgment
12 process enables an accurate judgment of the possibility of
13 evacuation of the preceding vehicle as a monitoring object based
14 on information of the position of the preceding vehicle, the
15 traveling path of the own vehicle and the objects in the
16 neighborhood of the preceding vehicle, not only the preceding
17 vehicle can be continued to be caught as a monitoring object,
18 but also every behavior of the preceding vehicle including the
19 change of the preceding vehicle from one to another can be detected
20 with quick responsibility and accuracy. As a result, the traveling
21 control can be executed stably in a manner similar to driver's
22 driving senses.

23 Thus, after the judging processes of the possibility
24 of evacuation of the preceding vehicle are executed using the
25 own traveling path C (Xprc[i], i = 0 to 23) at S207, the program

1 goes to S208 where it is judged from the result of the judgment
2 at S207 whether or not there is a possibility of evacuation of
3 the preceding vehicle.

4 If it is judged that there is no possibility of
5 evacuation of the preceding vehicle, the program goes to S209
6 wherein it is judged whether or not the turn signal switch 9 of
7 the own vehicle is turned on. If the turn signal switch 9 is turned
8 off, the program goes to S210 in which it is judged whether or
9 not the absolute value of the steering wheel rotation angle is
10 larger than a specified value, for example 90 degrees. If it is
11 smaller than the specified value, the program goes to S211 where
12 a new own traveling path E ($Xpre[i]$, $i = 0$ to 23) is based on
13 the own traveling path C ($Xprc[i]$, $i = 0$ to 23) and the own traveling
14 path D ($Xpre[i]$, $i = 0$ to 23) according to the following formula:

$$15 \quad Xpre[i] = Xprc[i]$$

16 where $i = 0$ to $(kpo - 2)$, $(kpo + 1)$ to 23

$$17 \quad Xpre[i] = (Xprc[i] + xpo \cdot \kappa) / (1.0 + \kappa)$$

18 where $i = kpo - 1, kpo$

19 In this embodiment, the own traveling path D is expressed only
20 by X coordinate xpo at the segment kpo of Z coordinate of the
21 preceding vehicle. Further, κ is a variable varying according
22 to the recognition of circumstances. When the recognition of
23 circumstances is inferior, κ is established to a large value.
24 That is, in the process of S211, as shown in Fig. 5c, taking the
25 case where the preceding vehicle changes the lane into

1 consideration, only the neighborhood of the preceding vehicle
2 is corrected with respect to the preceding vehicle so that the
3 ACC system 2 operates with accuracy.

4 Then, the program goes to S212 wherein the present own
5 path (Xprc[i], i = 0 to 23) is calculated from the own traveling
6 path E (Xpre[i], i = 0 to 23) newly calculated presently and the
7 own traveling path (Xpr(n-1)[i], i = 0 to 23) calculated in the
8 previous cycle and stored at S201 as follows:

9
$$Xpr(n)[i] = Xpr(n-1)[i] \cdot \phi - Xpre[i] \cdot (1.0 - \phi)$$

10 where ϕ is a value established according to traveling
11 conditions of the own vehicle. For example, when the vehicle
12 transfers from curved road to straight road, ϕ is established
13 to a small value so as to impose more weight on the own traveling
14 path E (Xpre[i], i = 0 to 23) calculated newly, presently and
15 otherwise ϕ is established to a large value so as to impose more
16 weight on the own traveling path (Xpr(n-1)[i], i = 0 to 23)
17 calculated in the previous cycle. As a result, the response in
18 accordance with the traveling conditions can be obtained.

19 On the other hand, in case where it is judged at S205
20 that there is no preceding vehicle, or in case where it is judged
21 at S208 that there is a possibility of evacuation, the program
22 goes to S213. Similarly, in case where it is judged at S209 that
23 the turn signal switch 9 is turned on, or in case where it is
24 judged at S210 that the absolute value of the steering wheel rotation
25 angle is larger than a specified value, the program goes to S213.

1 At S213, the present own traveling path (Xpr(n)[i],
2 i = 0 to 23) is calculated from the own traveling path C (Xprc[i],
3 i = 0 to 23) calculated at S204 and the previous own traveling
4 path (Xpr(n-1)[i], i = 0 to 23) stored at S201 in the following
5 manner:

$$6 \qquad Xpr(n)[i] = Xpr(n-1)[i] \cdot \phi - Xprc[i] \cdot (1.0 - \phi)$$

7 After the own traveling path is estimated, the program
8 goes to S103 where the preceding vehicle is extracted, leaving
9 the routine. The extraction of the preceding vehicle is performed
10 as follows:

11 First, the traveling region A is established based on
12 the traveling path of the own vehicle according to the solid object.
13 Further, the traveling region B is established based on at least
14 either of the traveling region A and road information (road
15 profile estimated from lane markers and side walls). Then, if
16 the detected solid object exists in the traveling region A and
17 if the duration for which the solid object stays in either of
18 the traveling regions A and B, is larger than a specified time
19 and if the solid object is a forward moving object and if the
20 object is nearest one to the own traveling vehicle 1, the solid
21 object is regarded and extracted as a preceding vehicle.

22 According to the embodiment of the present invention,
23 since the final own traveling path is calculated based upon the
24 own traveling path A (Xpra[i], i = 0 to 23) obtained from lane
25 marker and side wall data and the own traveling path B (Xprb[i],

1 i = 0 to 23) derived from the yaw rate of the own vehicle 1 and
2 the own traveling path D (Xprd[i], i = 0 to 23) calculated based
3 on the trace of the preceding vehicle, the own traveling path
4 can be estimated accurately, stably and securely.

5 Further, when the own traveling path C (Xprc[i], i =
6 0 to 23) is calculated from the own traveling path A (Xpra[i],
7 i = 0 to 23) and the own traveling path B (Xprb[i], i = 0 to 23)
8 and the own traveling path E (Xpre[i], i = 0 to 23) is newly calculated
9 using the own traveling path C (Xprc[i], i = 0 to 23) and the
10 own traveling path D (Xprd[i], i = 0 to 23) produced based on
11 the traveling trace of the preceding vehicle, since an accurate
12 judgment process of evacuation is executed using the own traveling
13 path C (Xprc[i], i = 0 to 23) and the own traveling path E (Xpre[i],
14 i = 0 to 23) is synthesized according to the result of the judgment,
15 unnecessary calculations according to every behavior of the
16 preceding vehicle can be effectively prevented from being made
17 and as a result an accurate calculation of the own traveling path
18 can be performed.

19 Further, the ON-OFF signal of the turn signal switch
20 9 and the value of the steering wheel rotation angle enable to
21 obtain the final own traveling path in a natural manner reflecting
22 driver's intention.

23 Furthermore, when the own traveling path E (Xpre[i],
24 i = 0 to 23) is calculated using the own traveling path C (Xprc[i],
25 i = 0 to 23) and the own traveling path D (Xprd[i], i = 0 to 23)

1 derived from the traveling trace of the preceding vehicle, since
2 the possibility of evacuation is judged not only according to
3 the behavior of the preceding vehicle but also according to that
4 of the solid object other than the preceding vehicle in the
5 neighborhood of the preceding vehicle, the judgment of evacuation
6 can be made more correctly.

7 The entire contents of Japanese Patent Application No.
8 Tokugan 2002-271906 filed September 18, 2002, is incorporated
9 herein by reference.

10 While the present invention has been disclosed in terms
11 of the preferred embodiment in order to facilitate better
12 understanding of the invention, it should be appreciated that
13 the invention can be embodied in various ways without departing
14 from the principle of the invention. Therefore, the invention
15 should be understood to include all possible embodiments which
16 can be embodied without departing from the principle of the
17 invention set out in the appended claims.

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